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(54) METHOD AND PLANT FOR SUPPLYING ENERGY TO AN ELECTRIC ARC FURNACE

(71) We, VEREINIGTE OSTERREICHISCHE EISENUND STAHLWERKE—ALPINE MONTAN AKTIENGESELLSCHAFT, a concern of the nationalised industry of the Republic of Austria, of Friedstrasse 4, Wien, Austria, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method and apparatus for supplying energy to an electric arc furnace by means of an electric generator which is driven by an engine.

The system for supplying energy to electric arc furnaces used for metallurgical processes are subjected to substantial loads by the short circuits which occur in a rapid irregular sequence during the operation of such furnaces. To minimize the effect of such loads on the power supply system, the power rating of the systems for supplying energy to electric arc furnaces must greatly exceed the furnace power. Because power supply systems having such a high power rating are not available everywhere, these electric arc furnaces used for metallurgical processes must be included in self-contained power supply systems although the electric generators of such systems are also subjected to large load fluctuations. These require an adaptation of sthe driving power to the instantaneous load on the electric generator so that constant supply frequencies are obtained at approximately constant speed. When the electric generator is unloaded because the furnace is de-energized during a short circuit, the power input of the electric generator must be correspondingly decreased so that the speed does not undesirably increase. When the electric generator is subsequently loaded because the short circuit has disappeared, the drive means should be capable of takinng up the sudden torque load without a loss in speed, if possible. This requirement involves problems not only as regards the automatic control of the drive means but also as regards the drive means themselves because the loading of the drive means will necessarily result in a slight decrease in speed before the automatic control system can respond. For this reason the drive means should be able to provide for surplus power so that the re-acceleration to the original speed can be effected in a minimum of time.

Particularly when an engine is used to drive the electric generator, these requirement regarding the means for driving the generator cannot be fulfilled without a waste of energy.

According to the present invention there is provided a method of supplying energy to an electric arc furnace by means of an electric generator driven by an engine, characterized in that a resistor having a power consumption that is comparable to that of the furnace is connected to the electric generator during any periods in which the furnace is de-energized during operation so that the engine is adapted to drive the electric generator with an approximately constant load and the thermal energy derived from electrical energy in the resistor is used to evaporate water. Because there is no need for a substantial automatic control action on the means for driving the electric generator, the problems otherwise involved in such control actions are also eliminated and the rated power of the plant can be fully utilized. Where the measures according to the invention are adopted, it is not required to operate the engine in a partial load range so that a sufficiently large surplus power is available and an automatic control in a larger range is enabled. For this reason, the electric arc furnace can be operated in a self-contained system which does not require a high structural expenditure.

It will be understood that the resistor which is adapted to be connected and disconnected may consist of an existing electric power supply network for receiving the surplus energy. In that case, a frequency-decoupling network and a synchronizer must be connected between the system for supply-

ing energy to the electric arc furnace and the external power supply network and expensive thyristor control systems are required for this purpose.

During load peaks, that steam produced by means of the resistor can be supplied to the engine, which consists of a turbine, so that surplus energy for compensating smaller speed drops can be made available although the rated power is fully utilized. This mode of operation can be adopted with gas turbines and with steam turbines because the mass flow through these turbines is changed by the supply of additional steam, provided that the prevailing temperature and pressure conditions are taken into account.

In the opposite case, the flow of fluid (steam or gas) through the turbine can be decreased during periods of decreased load so that the latter cannot result in a speed increase. The tapping of fluid from the turbine affords the advantage that the inlet temperature of the turbine can be held constant, which is not possible, e.g., when the fuel rate is changa.

When a steam turbine is used to drive the electric generator, the steam tapped from the turbine may be supplied to the steam generator which is heated by the resistor and the surplus energy which is thus stored can be recycled to the turbine as saturated steam during periods of increased load. In that case the steam generator is used also as a head-stabilizing steam accumulator.

Alternatively, the steam produced by means of the resistor may be added to the steam flowing from the main steam generator to the turbine and may be superheated together with the latter steam before entering the turbine. In that case, the auxiliary steam generator heated by means of the resistor communicates with the feed water system of the main steam generator and the surplus electrical energy can be used to drive the electric generator in a desirable manner.

To minimize the energy required for the operation of the plant for supplying energy to an electric arc furnace, the waste heat of the electric arc furnace should also be utilized. In a further embodiment of the invention this can be accomplished in that a waste heat steam generator is connected to the main steam generator and heated with the waste gases from the electric arc furnace. That waste heat steam generator may be additionally heated by a separate burner so that a temperature level which ensures a high efficiency is obtained.

The waste heat from the electric arc furnace may be utilized for other purposes too in that material to be processed in the electric arc furnace is preheated by the exhaust gases from said furnace.

Particularly desirable results will be obtained if exhaust gases from the waste heat steam generator are used to preheat material to be processed because the sensible heat of the exhaust gases can be utilized more completely in this way.

For this purpose, exhaust gases which leave the furnace for preheating material to be processed may be heated up by an additional burner and may then be supplied to a further steam generator.

When an internal combustion engine, a gas turbine, or a diesel engine rather than a steam turbine is used to drive the electric generator, the exhaust gases of such engine may also be used to heat a steam generator and the generated steam may be fed to a steam turbine. That steam turbine may drive a separate electric generator for supplying energy to a power supply network which includes only small loads and/or steady loads and which may be coupled to external power supply networks which have only a restricted power rating and for this reason cannot be used to supply the electric furnace. Such network may be independent of the network which is powered by the internal combustion engine and serves to supply energy to the electric arc furnace. Similarly, in plants comprising a steam turbine the surplus energy may be used to operate a separate steam turbine for driving an additional electric generator for feeding a separate network.

The methods which have been described hereinbefore may be carried out in a simple manner in a plant in which, in accordance with the invention, an electric resistance heating system of a steam generator is connected by a switch to a busbar, which is fed from the electric generator and serves to energize the electric arc furnace, and the switch is operable by an automatic control system in dependence on the load on the electric generator. An increase or decrease of the load on the generator in response to a de-energization or energization of the furnace could result in an increase or decrease in speed unless the means for driving the electric generator are properly controlled in response to such load changes. Such control of the means for driving the electric generator is not required where the measures taught by the invention are adopted because a heating resistor having a power input which corresponds to the changes of the load on the electric generator resulting from the changes in the operating conditions of the furnace is energized and de-energized, respectively in response to a decrease and increase of the load on the electric generator respectively caused by a de-energization or energization of the furnace. As a result, the load on the electric generator is at least approximately constant so that large automatic control actions on the driving engine are not required.

The invention will be more fully understood from the following description given by way of example only with reference to the figures of the accompanying drawing.

Figure 1 is a block circuit diagram showing a plant which embodies the invention and serves to supply energy to an electric arc furnace. This plant comprises a steam generator which is heatable by electrical energy supplied from the busbar for the electric arc furnace and which is connected to the steam turbine for driving the electric generator for feeding said busbar.

Figure 2 shows a plant which is similar to that of Figure 1 and in which the auxiliary steam generator is included in the steam circuit of the main steam generator.

Figure 3 shows a plant which is similar to that of Figure 2 and in which the waste heat from the electric arc furnace is also used to generate steam.

Figure 4 shows a plant which serves to supply energy to an electric arc furnace and in which a separate steam turbine is fed from the auxiliary steam generator.

Figure 5 shows a plant which serves to supply energy to an electric arc furnace and in which the electric generator is driven by a gas turbine and the sensible heat of the exhaust gases from the turbine is utilized to generate additional steam.

In accordance with the block circuit diagrams, an electric arc furnace 1 is fed in the usual manner from a busbar 2 via a furnace switch 3, an isolating transformer 4 and a choke 5. The busbar 2 is supplied with energy by an electric generator 6, which in accordance with Figures 1 to 4 is driven by a steam turbine 7, which is supplied with steam from a main steam separator 8 through a superheater 9 and a quick-action shut-off valve 10. The steam which has expanded in the turbine 7 is condensed in a condenser 11. The condensate is fed by a pump 12 to a feed water container 13 and is fed from the latter by a feed water pump 14 to the steam generator 8.

In addition to the main steam generator 8, an auxiliary steam generator is provided, which has an electric resistance heater 16, which is connected by a switch 17 to the busbar 2 for the electric arc furnace 1. The switch 17 is operated by an automatic control system 18, which tends to hold the load on the electric generator approximately constant by causing the resistance heater 16 to be energized and de-energized in dependence on the load on the electric generator. For this purpose, the load on the busbar 2 and the frequency of the electric generator are sensed and the speed of the electric generator is held substantially constant by an appropriate control of the load thereon. When the furnace 1 is de-energized by the switch 3 in response to a short circuit, the resulting unloading of the busbar is sensed by the automatic control system 18, which then closes the switch 17 so that an additional load is applied, which consists of the electric resistance heater 16 and corresponds to the load otherwise applied by the furnace. In response to the subsequent energization of the electric arc furnace 1, the resistance heater 16 is de-energized. The load on the electric generator 6 is thus held constant in spite of the de-energization of the furnace. The electrical resistance of the heater 16 may be adjustable for an adaptation of the power consumption of the resistance heater 16 to the power of the furnace.

Because the load on the electric generator is thus held approximately constant in that the resistance heater 16 is energized when the furnace is de-energized, an automatic control of the steam turbine 7 in a large range is not required so that the steam turbine can be operated in a mode which is desirable for such engine. Whereas it will be understood without further explanation that the temporary energization of the resistance heater 16 cannot result in a perfectly constant load, irregularities which result from these load fluctuations are relatively small and can be compensated at least in part by suitable flywheels. Besides, the surplus energy which is made available in the steam generator 15 by the resistance heater 16 can be used to supply any peak loads. For this purpose the steam generator 15, which consists preferably of a steam-accumulating boiler, is connected by a tap valve 19 to an input tap of the turbine 7 so that additional driving energy can be made available by the supply of additional steam and a rapid re-acceleration of the electric generator 6 to the proper speed is thus ensured.

On the other hand, if the generator speed increases in an undesired manner, steam can be tapped from the turbine 7 through discharge conduit 20 and a valve 21 in response to an undesired increase of the speed of the electric generator. The tapped steam is either fed through a non-return valve 22 to a feed water tank 13 or through a feed valve 23 to a steam generator 15. The energy which is extracted from the turbine 7 with the tapped steam can thus be stored in the steam generator 15 and can be made available through a succeeding turbine input tap.

The steam from the steam generator 15 may alternatively be used to preheat the condensate in a heat exchanger 24. The condensate formed in the heat exchanger 24 is added to the condensate which has been formed from steam in condenser 11 and together with the latter condensate is fed to the feed water tank 13. Because it will be understood that shut-off or other valves must be provided in the conduits to control the flow of steam and/or condensate, such

valves are not shown in the drawings for the sake of clearness.

For feeding feed water to the auxiliary steam generator 15, the latter is connected to the feed water tank 13. The supply of feed water may be controlled by a valve 26, which is responsive to a liquid level indicator.

The surplus energy which is produced by the electric generator 6 when the electric arc furnace 1 is de-energized and which is stored in the auxiliary steam generator 15 may be added directly to the steam delivered by the main steam generator 8. In such an arrangement, shown in Fig. 2, the steam from the auxiliary steam generator 1 is fed through the discharge valve 19 to the steam delivered by the main steam generator 8 and together with the latter steam is heated in the superheater 9 before entering the turbine.

The plant shown in Figure 3 for supplying energy to an electric arc furnace 1 is similar to the plant shown in Figure 2 but comprises means in which the waste heat from the electric arc furnace 1 is used to generate steam. For that purpose the mean steam generator 8 and waste heat steam generator are combined in a unit, which is connected to an exhaust gas conduit 27 from an electric arc furnace 1 so that the waste heat from the electric arc furnace can be utilized by a heat exchange. The exhaust gas from the electric arc furnace 1 can be additionally heated by an addition of hot gases or by a burning of fuel. This is indicated in Figure 3 by a fuel supply conduit 28 and by a combustion air conduit 30, which is supplied from a compressor 29. The conduits 28 and 29 lead to a burner 31. The flue gas leaving the steam generator 8 is sucked by an exhaust fan 32 through an exhaust gas filter 33 and is subsequently discharged into the open through a chimney, not shown.

The surplus energy which is made available in the steam generator 15 by the electric heater 16 need not be used to drive the electric generator 6. As is shown in Figure 4, that energy may be used to operate a separate, self-contained system, which comprises a steam accumulator 34, from which condensate is fed by a pump 35 to a waste heat boiler 36, which is connected to the exhaust gas conduit 27 of the electric arc furnace 1 and which can be additionally heated by a burner 37. The steam produced in the waste heat boiler 36 is recycled through conduit 38 to the steam accumulator 34 and from the latter through conduit 39 to a superheater 40, from which superheated steam is supplied to a steam turbine 41, which is succeeded by a condensor 42, a pump 43 and a feed water tank 44. From the latter, feed water is fed by a pump 45 to the steam accumulator 34, which may be additionally heated. The pump 45 may also be used to supply feed water to the steam generator 15.

The turbine 41 drives an electric generator 46, from which separate consumers 48 are supplied via a busbar 47. An external power supply network 49 may be connected to the busbar 47 because the electric generator 46 can operate independently of the load changes which are due to the operation of the furnace.

In addition to the waste heat boiler 36, an additional steam generator 50 may be used to generate steam. The residual waste heat of the exhaust gases from the furnace may be used in such steam generator 50. A further utilization of the heat content of the exhaust gases may be ensured by a preheating furnace 51, which is included in the exhaust gas conduit from the waste heat boiler 36 and serves to preheat the material to be processed in the electric arc furnace.

It will be understood that the steam turbine for driving the electric generator 6 may be replaced by any other suitable engine, such as a gas turbine or a diesel engine. Figure 5 shows the use of a gas turbine 52 for driving the electric generator 6. The air required for combustion is sucked by the compressor 53 of that gas turbine 52 and is fed under pressure to a combustion chamber 54, which is connected to a fuel conduit 55. Part of the compressed air can be blown off through a blow-off valve 56 to vary the mass flow through the turbine 52 in compensation of speed increases which are due to load decreases involved in the operation of the furnace. The temperature of the combustion gases entering the turbine 52 may be varied by a control of the fuel supply through conduit 55 so that the temperature conditions are constant in spite of the decrease in mass flow. When a load is applied, the blow-off valve 56 may be closed and the fuel supply may be increased at the same time to re-establish the original turbine power. These control actions will not give rise to difficulties in the operation of the turbine 52.

In accordance with Figure 5, the sensible heat of the hot exhaust gases from the turbine is additionally utilized to heat a superheater 57, a steam generator 58 and a feed water preheater 59. A manifold 60 collects saturated steam not only from the steam generator 58 but also from the steam generator 15 and a waste heat boiler 36 and delivers saturated steam to a superheater 57 for feeding a turbine 61. The waste heat boiler 36 is heated by the exhaust gases from the furnace. As a result, superheated steam at an adequate rate is always available for the operation of the turbine 61 for driving the electric generator 62 and consumers 64 or an external power supply network 65 may be supplied with electrical

energy through a busbar 63 because the drive of the electric generator 62 and the load thereon are independent from the load fluctuations which are due to the furnace. Steam 61 which has expanded in the turbine is condensed in a condenser 66, and the condensate is fed by a pump to a feed water tank 68, from which feed water is fed by a feedwater pump 69 to the several steam generators 58, 15, and 36. In an additional circuit 70 connected to the feed water tank 68, part of the feed water is circulated by means of a pump 71 through the heat exchanger 59 and is preheated therein.

WHAT WE CLAIM IS:—

1. A method of supplying energy to an electric arc furnace by means of an electric generator driven by an engine, characterized in that a resistor having a power consumption that is comparable to that of the furnace is connected to the electric generator during any periods in which the furnace is de-energized during operation so that the engine is adapted to drive the electric generator with an approximately constant load, and the thermal energy derived from electrical energy in the resistor is used to evaporate water.

2. A method as claimed in claim 1, characterized in that steam produced by means of the resistor is supplied during peak loads to a turbine which constitutes the engine.

3. A method as claimed in any of claims 1 to 2, characterized in that fluid (steam or gas) is tapped off during periods of decreased load from a turbine which constitutes the engine.

4. A method as claimed in claim 1, characterized in that steam tapped from a steam turbine which constitutes the engine is fed to a steam generator heated by means of the resistor.

5. A method as claimed in any of claims 1 to 4, characterized in that steam generated in an auxiliary steam generator by means of the resistor is added to and heated jointly with steam to be delivered from a main steam generator to a steam turbine which constitutes the engine, and the auxiliary steam generator and main steam generator are connected to a common feed water system.

6. A method as claimed in any of claims 1 to 5, characterized in that a waste heat steam generator is connected to the main steam generator and is heated with exhaust gases from the electric arc furnace.

7. A method as claimed in claim 6, characterized in that the waste heat generator is additionally heated by a separate burner.

8. A method as claimed in any of claims 1 to 7, characterized in that material to be processed in the electric arc furnace is preheated with exhaust gases from the electric arc furnace.

9. A method as claimed in claim 7 or 8, characterized in that exhaust gases from the waste heat generator are used to preheat material to be processed.

10. A method as claimed in claim 8 or 9, characterized in that exhaust gases from the furnace for preheating material to be processed are heated up by an additional burner and then supplied to a steam generator.

11. A method as claimed in any of claims 1 to 10, characterized in that exhaust gases from an internal combustion engine which constitutes said engine are used to heat a steam generator which is preferably used to feed a steam turbine.

12. A method as claimed in any of claims 1 to 11, characterized in that steam produced by means of the resistor is fed to a steam turbine for driving an electric generator for feeding a separate power supply network.

13. Apparatus for carrying out the method according to any one of claims 1 to 12, wherein an electric resistance heating system of a steam generator is connected by a switch to a busbar, which is fed from the electric generator and serves to energize the electric arc furnace, and the switch is operable by an automatic control system in dependence on the load on the electric generator.

14. A method of supplying energy to an electric arc furnace, substantially as described hereinbefore.

15. A plant for supplying energy to an electric arc furnace, substantially as described hereinbefore with reference to or as shown on the accompanying drawings.

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FIG.1

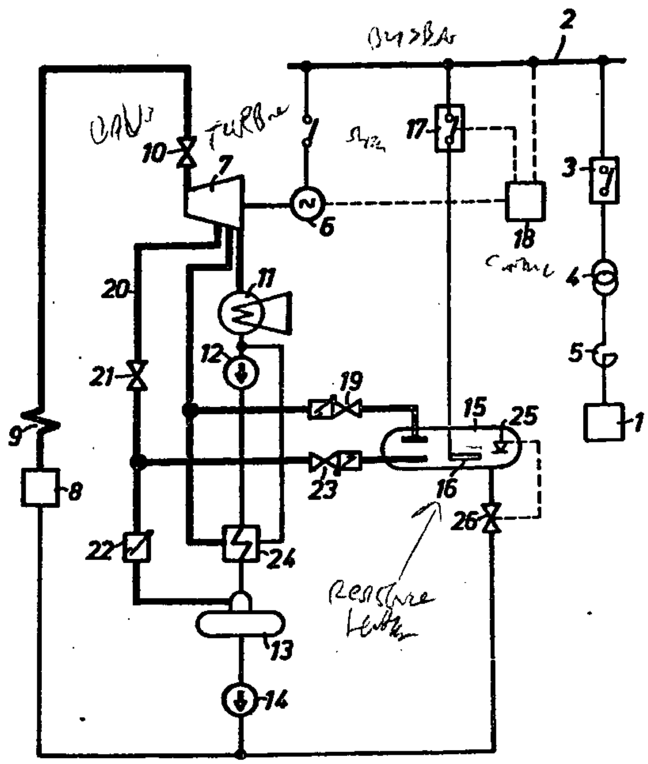


FIG. 2

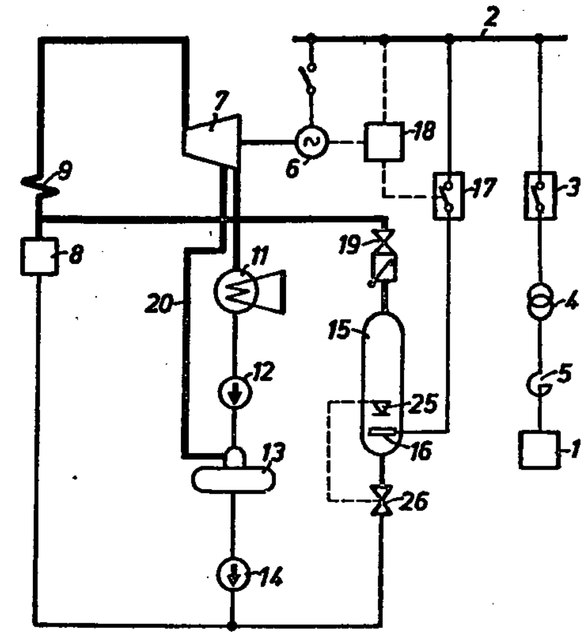
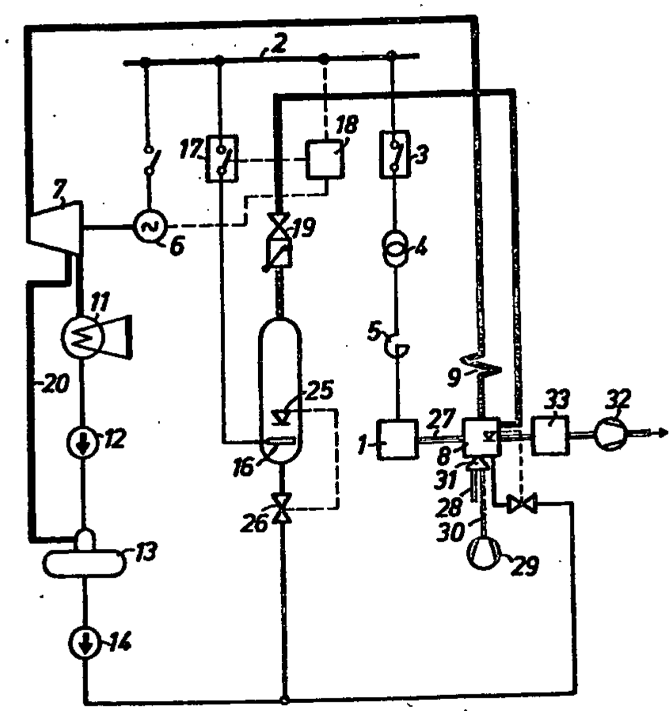


FIG. 3



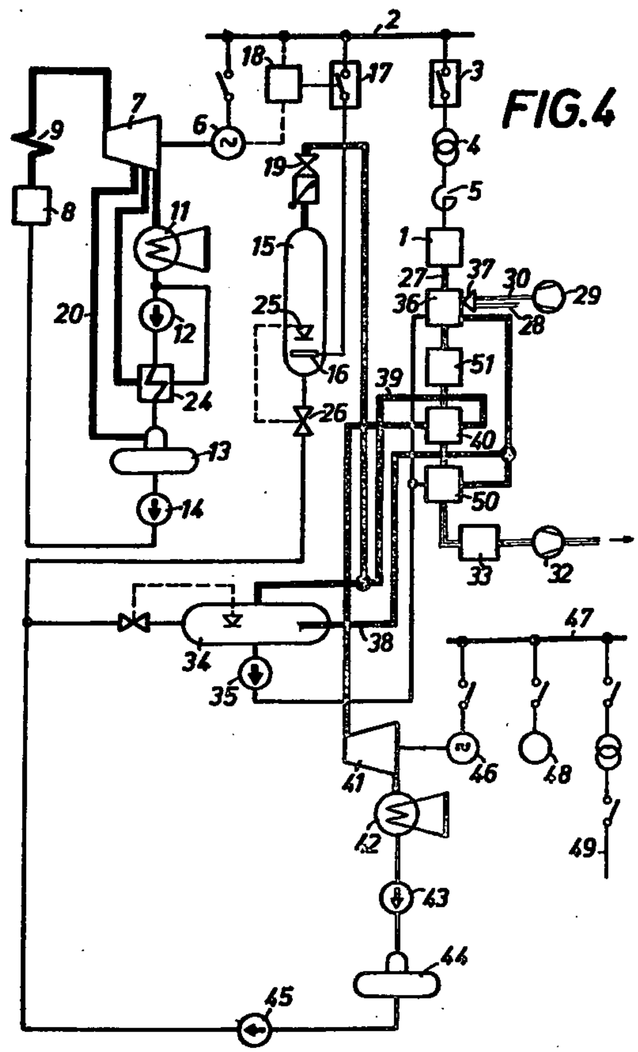

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FIG.4

1572204 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 5

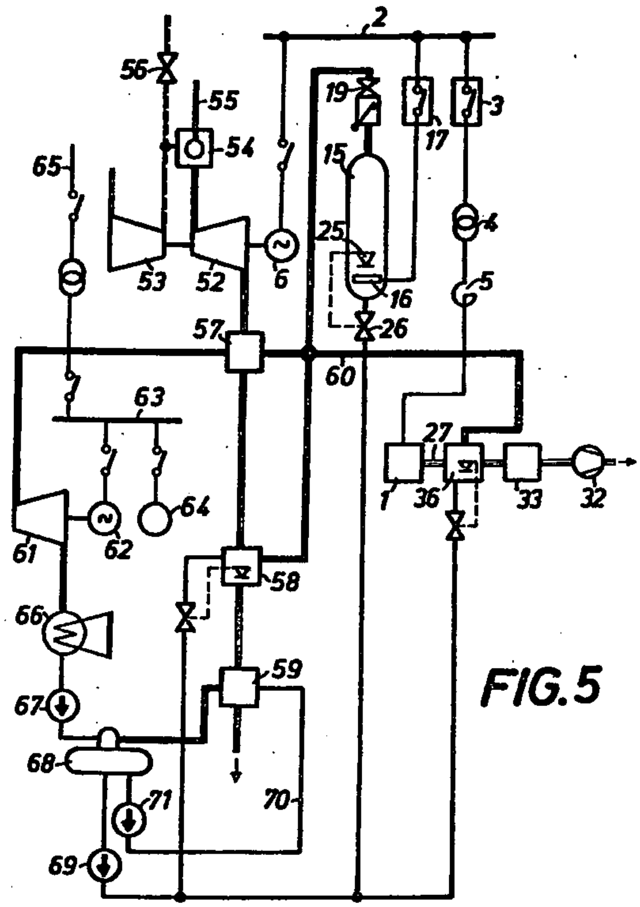

FIG.5